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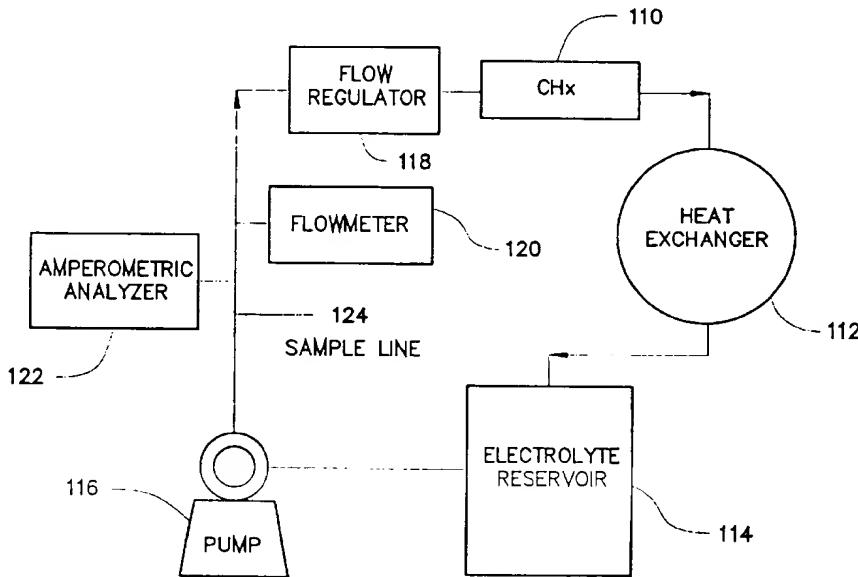
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(54) Title: CORROSION CONTROL UTILIZING A HYDROGEN PEROXIDE DONOR



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(57) Abstract: The present invention describes an innovative means of inhibiting corrosion of metals which experience active-passive transition in contact with an electrolyte. This invention incorporates hydrogen peroxide and/or peroxycarboxylic acids or their constituents to inhibit corrosion by inducing passivation of the metal. Application of this technology reduces the potential for fouling, scaling and deposition as well as outperforming existing methods of corrosion control in these applications.

CORROSION CONTROL UTILIZING A HYDROGEN PEROXIDE DONOR  
FIELD OF THE INVENTION

This invention relates to a method of inhibiting corrosion as well as inhibiting scale and deposit formation resulting from the saturation of mineral salts, and buildup of corrosion byproducts. The invention generally relates to the inhibition of corrosion of metals in contact with an electrolyte and the reduction of insulating films owing to scale formation/deposition. The invention most particularly relates to the inhibition of corrosion on metals which experience active-passive transition by application of a hydrogen peroxide donor. Illustrative of such metals are steel(s), aluminum, titanium or mixtures thereof; however the instant invention contemplates the treatment of any metal which is capable of experiencing active/passive transitions when exposed to passivating agents.

BACKGROUND OF THE INVENTION

Corrosion of metals, particularly those metals found in cooling water circulating systems, and most particularly those in heat exchangers, are of critical concern.

In industrial cooling systems, water from rivers, lakes, ponds, wells, wastewater treatment plant effluent etc., is employed as the cooling media for heat exchangers. Such waters can contain a variety of either dissolved and/or suspended materials such as mineral salts, metals, organics, silt, mud etc.

The cooling water from a heat exchanger is typically passed through a cooling tower, spray pond or evaporative system prior to discharge or reuse. In such systems, cooling is achieved by evaporating a portion of the water passing through the system. Because of the evaporation

1 that takes place during the cooling, both dissolved and  
2 suspended solids concentrate. The concentrating of  
3 various anionic ions such as chlorides and sulfates can  
4 increase the rate of corrosion of the metals making up the  
5 cooling system. This is especially true with the metals  
6 making up the heat exchangers that are experiencing higher  
7 temperatures.

Furthermore, contaminants such as hydrogen sulfide can also increase corrosion rates. Likewise, mineral salts, for example those of calcium and magnesium can induce scaling of the heat exchanger. A scale common in cooling systems is calcium carbonate. Other scales or deposits such as calcium phosphate or iron can also inhibit heat transfer as well as induce under-deposit corrosion.

16 Deposit formation on heat exchangers seriously  
17 reduces heat transfer. Corrosion byproducts can form on  
18 the metal surface where a corrosion cell has formed.  
19 Deposits from metal oxides, silt, mud, microbiological  
20 activity, and process contamination can reduce the  
21 efficiency of heat transfer as well as increase corrosion.

Reducing the corrosion, scaling and deposition of heat exchangers and associated cooling system equipment is thus essential to the efficient and economical operation of a cooling water system. Excessive corrosion of the metallic surfaces can cause the premature failure of process equipment, necessitating down time for the replacement or repair of the equipment. Additionally, the buildup of corrosion products on the heat transfer surfaces impedes water flow and reduces heat transfer efficiency thereby limiting production or requiring downtime for cleaning.

## Aspects of Corrosion

34 In order for corrosion to occur, a corrosion cell  
35 must form. The corrosion cell consist of two half cells,

1 the cathode, and the anode.

2       The cathode is defined as the point where the  
3 reduction of a reducible substance takes place. In waters  
4 where the pH is greater than 4.2 (like that of a cooling  
5 water system), the primary reducible substance is oxygen.  
6 The steps involved with the cathode include: oxygen  
7 diffusion to the metal surface, adsorb by either physical  
8 or chemical adsorption, electron transfer, rearrangement  
9 with other adsorbed materials (i.e. water and electrons  
10 with subsequent formation of hydroxide ions), de-sorption  
11 of the newly formed byproduct (hydroxide), and diffusion  
12 into the bulk meter. With increased concentration of  
13 hydroxide ions, oxygen diffusion and adsorption rates are  
14 reduced.

15       The anode is defined as the point where dissolution  
16 of metal ions occurs. The dissolution of metal ions at  
17 the anode is a chemical process. The reaction forms  
18 ferrous hydroxide. Initially, the potential at the anode  
19 is low; however with time, the electrical potential at the  
20 anode increases. The increased potential is the result of  
21 the increased concentration of metal ions (result of  
22 dissolution) in the immediate vicinity of the anode. The  
23 increased concentration of metal ions induces the  
24 formation of a Metal Ion Concentration Cell, as well as  
25 the reduction of oxygen. The increasing concentration of  
26 cationic charged ions at the anode increases the  
27 electrical potential of the anode.

28       General corrosion is defined as a state where the  
29 potential of the cathode decreases with time while the  
30 potential at the anode increases. At some point, the  
31 potentials of the cathode and anode shift or find  
32 neighboring electrodes of stronger or weaker potential.  
33 This shifting or jumping is the result of the mechanisms  
34 already described. As the hydroxide concentration at the  
35 cathode increases, oxygen adsorption decreases, and the

1       cathodes potential goes down. At the anode, where the  
2       concentration of cationic ions increases, the demand for  
3       electrons increases, so the potential goes up. This  
4       process of electrode reversal continues across the surface  
5       of the metal resulting in a uniform loss of metal.

6       Pitting corrosion refers to a condition where the  
7       potential surrounding the anode is high (cathodic) and  
8       electron flow is not distributed across many anodes,  
9       therefore the electron comes from a local anode. Pitting  
10      corrosion is of great concern because of the high loss of  
11      metal from a localized area. At a metal loss rate of  
12      several mils per year (MPY), general corrosion would take  
13      many decades of continued corrosion before resulting in  
14      failure of the part, e.g. of a heat exchanger. However,  
15      in pitting corrosion, the electron flow and subsequent  
16      metal loss is from a localized area. Pitting corrosion  
17      often results in equipment failure long before reaching  
18      the expected life of the equipment, e.g. the heat  
19      exchanger.

20      Pitting corrosion occurs when the cathodic surface  
21      has been depolarized. Chlorides for example, compete for  
22      the metal surface with the oxygen donor. When a chloride  
23      ion is adsorbed at the metal surface, it prevents the  
24      oxygen from reaching the surface. The potential at the  
25      site is reduced, and the area becomes anodic. This induces  
26      a high flux of electrons to flow from the localized site  
27      to the surrounding cathode.

28      Passivation can be defined as the loss of chemical  
29      reactivity exhibited by certain metals and alloys under  
30      specific environmental conditions. The onset of  
31      passivation is associated with the formation of an oxide  
32      layer that is resistant to further oxidation.

33      The mechanism of passivation, as it relates to  
34      ferrous metal surfaces, involves the dissolution of metal  
35      ions, followed by formation of a ferrous hydroxide layer,

1 followed by conversion to an insoluble ferric oxide by  
2 reaction with oxygen. Analysis of passive films indicates  
3 a layered structure with an outer layer of gamma iron  
4 oxide and an inner layer of magnetite.

5 Passivation occurs when we have established  
6 sufficient oxidation potential. At low oxidation  
7 potential, insufficient concentrations of oxidizer exist  
8 to establish a homogenous oxide layer; distinct anodes  
9 and cathodes exist. When sufficient oxidizer is present,  
10 the electrical potential of the entire surface is  
11 increased. The concentration of oxidizer is sufficient to  
12 induce the "flash" formation of an oxide layer. In other  
13 words, the oxidizer concentration is sufficiently high to  
14 react with the ferrous hydroxide across the entire metal  
15 surface. With increased oxidation potential, the current  
16 density increases. The current density required to induce  
17 passivation is called the critical current. At yet higher  
18 oxidizer concentrations, aggressive attack of the oxide  
19 layer occurs, and the corrosion rates increase; this is  
20 termed the transpassive region.

21 Passivation is a process requiring oxygen. Therefore,  
22 inhibitors that induce passivation must increase the  
23 oxidizing potential or make better use of the oxidizer  
24 present.

25 Inhibitors such as chromate, nitrite and hydroxide  
26 raise the oxidizing potential of the solution by directly  
27 supplying oxygen to the anode to react with the metal ions  
28 thereby reducing the formation of a metal oxide. For this  
29 reason, these inhibitors can be used in solutions without  
30 oxygen present. These oxidizing inhibitors are involved  
31 with direct oxidation of the ferrous hydroxide to ferric  
32 oxides.

33 Inhibitors such as phosphate, silicate, borate and  
34 molybdate are non-oxidizing inhibitors which form  
35 complexes with iron (III) species so as to stabilize them

1 from disproportionation (the transformation of a substance  
2 into two or more substances by oxidation or reduction) to  
3 the more soluble Fe (II) species until reaction with  
4 dissolved oxygen creates the more immune oxides. These  
5 inhibitors do require the presence of oxygen to promote  
6 passivation. Their performance can be enhanced with the  
7 addition of a peroxide compound where peroxide is used to  
8 enhance the formation of a passive oxide film.

9 Anodic inhibition is desired from an operational  
10 viewpoint since the oxide film is very thin, and the  
11 corrosion rates are lower than that achieved by cathodic  
12 inhibition. However, the potential drawback is that if  
13 the film breaks are not repaired, due to insufficient  
14 inhibitor concentrations for example, rapid pitting may  
15 occur. This is the result of the fact that the cathodic  
16 reaction can occur all over the passive surface, but the  
17 anodic reaction (metal dissolution) can only occur at  
18 broken film sites.

19 Chromate treatments have been long recognized as the  
20 standard to compare other treatment programs. Chromates,  
21 induce the formation of a uniform oxide film thereby  
22 inducing passivation of the metal surface.

23 While chromate programs could be run at higher pH  
24 many were operated at lower pH (6.5 - 7.5). This  
25 significantly lowered the potential for scale formation.

26 Chromate technology has been eliminated from most  
27 applications involving cooling water treatment due to the  
28 environmental and human health hazards. Since the  
29 elimination of chromates, the most common treatment  
30 methodologies now incorporate technologies that increase  
31 scale and fouling potential.

32 Anodic phosphate treatments require levels of  
33 phosphate exceeding those allowed by the natural  
34 solubility of phosphate when in the presence of calcium.  
35 To stabilize phosphates and inhibit scale formation,

1 polymers that stabilize the formation of calcium phosphate  
2 salts are applied. Also, in some areas, lower phosphate  
3 levels are required to meet environmental restrictions.

4 Low phosphate levels can be achieved by incorporating  
5 a cathodic inhibitor like zinc. Zinc is a cathodic  
6 inhibitor that precipitates at the cathode by forming zinc  
7 hydroxide. Concentrations of peroxide and  
8 peroxy carboxylic acids can be reduced with the addition of  
9 a cathodic inhibitor such as zinc.

10 Again, because of the limited solubility of zinc,  
11 polymers are commonly fed to help prevent fouling from  
12 precipitation. Also, in many areas, zinc has environmental  
13 implications.

14 Using existing treatment methods, operating cost  
15 increased, and in many operating conditions such as high  
16 heat flux and/or high chlorides, results are less than  
17 desirable.

18 Thus, what is needed in the industry is a treatment  
19 program that is effective at inhibiting corrosion -under  
20 various heat flux and water chemistry conditions, as well  
21 as being environmentally innocuous.

22

23 DESCRIPTION OF THE PRIOR ART

24 US Patent No. 5,800,732 describes the use of hydrogen  
25 peroxide as a means of controlling microbial activity in  
26 an all-in-one treatment for cooling water.

27 US Patent No. 4,977,292 describes the development of an  
28 organic phosphorous compound using hydrogen peroxide as an  
29 oxidizer to initiate the oxidation reaction.

30 US Patent No. 5,382,367 describes the use of hydrogen  
31 peroxide in cooling water systems to control  
32 microbiological activity in said systems.

33 US Patent Nos. 5,980,758, 5,785,867, 5,658,467 and  
34 5,494,588 describe the use of peracetic acid with non-  
35 oxidizing biocides to inhibit growth of microorganisms.

1        The prior art fails to describe the use of peroxide  
2        and/or peroxy carboxylic acids as standalone corrosion  
3        inhibitors, much less passivating agents, for cooling  
4        water treatment. Furthermore, no prior art reference  
5        describes the use of these compounds as on-line deposit  
6        control and deposit removal agents for said application.

7

8        SUMMARY OF THE INVENTION

9        The instant invention is directed toward a method  
10      which provides superior corrosion inhibition, particularly  
11      to those areas experiencing heat transfer; namely the heat  
12      exchangers where corrosion and scale potential is most  
13      prevalent. The instant process recognizes the fact that  
14      both hydrogen peroxide and peroxy carboxylic acids are  
15      strong oxidizing agents having important similarities to  
16      chromate (VI) in that they are anionic oxidizers.

17       Since they function as anionic oxidizers, these  
18      compounds have high solubility in water and readily  
19      diffuse to the metal surface. Being strong oxidizers as  
20      well as oxygen donors, they are able to directly supply  
21      the oxygen needed to induce passivation.

22       The instant process utilizes these compounds as  
23      corrosion inhibitors and passivators to achieve  
24      performance equal to or exceeding that obtained by  
25      chromate. Such performance has been demonstrated under  
26      high heat load conditions and/or in the presence of  
27      corrosion inducing ions such as chlorides. These  
28      compounds also provide an environmentally innocuous  
29      treatment that eliminates the need for other corrosion  
30      inhibitors such as zinc and phosphate based treatments, as  
31      well as their supporting polymer treatment. The instant  
32      invention teaches an innovative treatment technology  
33      having application wherever removal of scale or deposits  
34      in contact with an electrolyte is required. The invention  
35      also teaches effective removal of insulating films while

1 inhibiting corrosion (especially under heat transfer) and  
2 can be effectively used to improve operational performance  
3 without suffering loss of system integrity or production  
4 time.

5 The chemistry selected for removal of the insulating  
6 layers is based on the composition of the deposits. In the  
7 test, ferrous oxide was the primary composition and  
8 therefore, peroxydic acid solution or mineral acid was  
9 effective at removing the deposit. Other chelating,  
10 sequestering, and dispersing agents could also provide  
11 effective results when used in conjunction with  
12 peroxydic acid(s) solutions.

13 Accordingly, it is an objective of the instant  
14 invention to utilize hydrogen peroxide donors as corrosion  
15 inhibitors and passivators to achieve performance equal to  
16 or exceeding that obtained by chromate .

17 It is a further objective of the instant invention to  
18 provide an environmentally innocuous treatment that  
19 eliminates the need for other corrosion inhibitors such as  
20 zinc and phosphate based treatments, as well as their  
21 supporting polymer treatment.

22 It is yet another objective of the instant invention  
23 to teach a treatment technology having application  
24 wherever removal of scale or deposits in contact with an  
25 electrolyte is required.

26 It is a still further objective of the invention to  
27 teach effective removal of insulating films while  
28 inhibiting corrosion (especially under heat transfer)  
29 thereby improving operational performance without  
30 suffering loss of system integrity or production time.

31 Other objects and advantages of this invention will  
32 become apparent from the following description taken in  
33 conjunction with the accompanying drawings wherein are set  
34 forth, by way of illustration and example, certain  
35 embodiments of this invention. The drawings constitute a

1 part of this specification and include exemplary  
2 embodiments of the present invention and illustrate  
3 various objects and features thereof.  
4

5 BRIEF DESCRIPTION OF THE FIGURES

6 Figure 1 is illustrative of a circulating system useful  
7 for conducting tests replicating a typical cooling water  
8 treatment application;

9 Figure 2 illustrates a cross-sectional view of a MENTOR  
10 CHx device;

11 Figure 3 is a graphical representation of Electro Chemical  
12 Noise (ECN) in the presence of Chromate;

13 Figure 4 is a graphical representation of ECN in the  
14 presence of Hydrogen Peroxide;

15 Figure 5 is a graphical representation of ECN in the  
16 presence of Peroxide-Citric Acid;

17 Figure 6 is a graphical representation of Heat Transfer  
18 During Cleaning ;

19 Figure 7 is a graphical representation of ECN During  
20 Cleaning;

21 Figure 8 is a graphical representation of Activity Factor  
22 (AF) During Cleaning.

23

24 DETAILED DESCRIPTION OF THE INVENTION

25 In accordance with Figure 1, a system was developed  
26 incorporating the use of a heated metal element, sensors  
27 for monitoring electrochemical noise corrosion, linear  
28 polarization, and heat transfer efficiency. Figure 1 is  
29 illustrative of a circulating system useful for conducting  
30 tests replicating a typical cooling water treatment  
31 application. Specifically, the instant device is  
32 comprised of a system that incorporates: a MENTOR CHx heat  
33 transfer device (more particularly described in Figure 2)  
34 110 that is made of the metallurgy to be tested. The  
35 metallurgy under heat transfer is in contact with an

1 electrolyte which is pumped via pump 116 through a heat  
2 exchanger 112 through which electrolyte from electrolyte  
3 reservoir 114 is passed. The electrolyte flow rates and  
4 rates of heat transfer are adjusted to desired levels by  
5 adjusting flow regulator 118. A flowmeter 120 is in fluid  
6 communication for ease of adjustments. If added, the  
7 concentration of a passivator is measured using a  
8 standardized amperometric analyzer. A sample line 124 is  
9 optionally provided for convenience in withdrawing samples  
10 for testing.

11 Now with further reference to Figure 2, a block 210  
12 is comprised of a series of pieces of the desired  
13 metallurgy 212 that are joined with an insulating material  
14 214 placed between each adjoining piece. This series of  
15 adjoined pieces will be designated the "block". A hole  
16 (not shown) is incorporated at some part of the  
17 construction process through which the electrolyte will  
18 contact the block. The metal pieces making up the block  
19 are equipped with appropriate sensing apparatus (not  
20 shown) for the sensing of ECN and LPR. Other sensing  
21 apparatus for determination of temperature gradients, heat  
22 transfer coefficients, etc. can be applied in a way that  
23 does not interfere with the performance of ECN and LPR  
24 sensing apparatus. The block is equipped with a device  
25 216 to provide heat thru the block. The block is combined  
26 with other supporting equipment necessary for replicating  
27 the operational environment of the heat transfer equipment  
28 in question. This can include, but is not limited to,  
29 equipment necessary for replicating electrolyte flow rate,  
30 electrolyte chemical parameters, and skin temperature at  
31 the heat exchanger electrolyte interface, etc.

32 The process control parameters are adjusted and  
33 controlled to replicate the operational environment at the  
34 heat exchanger metal-electrolyte interface. The heated  
35 element was made of 1010 carbon steel. A circulation pump

1 was attached to a reservoir pump the water of desired  
2 chemistry through the testing element, a cooling coil and  
3 back to the reservoir.

4 The chemistry selected for removal of the insulating  
5 layers is based on the composition of the deposits.  
6 Therefore, in the following tests, since ferrous oxide was  
7 the primary composition, a peroxydic acid solution or  
8 mineral acid was chosen for effectively removing the  
9 deposit. Other chelating, sequestering, and dispersing  
10 agents could also provide effective results when used in  
11 conjunction with peroxyacrylic acid(s) solutions.

12 Water was prepared having the following chemical  
13 characteristics:

14 Calcium as  $\text{CaCO}_3$  = 110 ppm

15 Total Alkalinity as  $\text{CaCO}_3$  = 66 ppm

16 Chloride as  $\text{Cl}^-$  = 25 ppm

17 pH = 7.9

18 The 1010 carbon steel block temperature was set to  
19 152°F which achieved a calculated skin temperature of  
20 144°F. Flow rate through the CHx was set at 3.8gpm which  
21 equates to a velocity of 4ft/sec. Steady state conditions  
22 were achieved and held during testing.

23 EXAMPLES:

24 Baseline - Chromate Test

25 Baseline data for chromate treatment was achieved using  
26 laboratory grade sodium chromate. Initially the system was  
27 treated with levels 4 times (1600 ppm) the normal  
28 concentration of chromate (as  $\text{CrO}_4$ ) to induce passivation.  
29 After 2 hours of circulation under heat transfer, some of  
30 the water was removed while it was replaced with identical  
31 quality makeup water without the chromate. The operating  
32 pH stabilized at 7.7 by the addition of the  $\text{H}_2\text{SO}_4$ . This  
33 dilution continued until the chromate level dropped to the  
34 test concentration of (330 ppm). The system was allowed to  
35 operate under steady state conditions to determine

1 corrosion rates under the described conditions as depicted  
2 in Figure 5.

3 Peroxide Test

4 The system was allowed to circulate under heat transfer  
5 until it reached steady state. The water was treated with  
6 hydrogen peroxide to achieve an initial dosage of 200ppm.  
7 The pH of the solution was adjusted to 7.4 by the addition  
8 of H<sub>2</sub>SO<sub>4</sub>. After reaching steady state, the ECN was  
9 monitored and recorded as illustrated in Figure 4. The  
10 system was then flushed until peroxide was undetectable  
11 and the pH of the circulating water equaled the flush  
12 water.

13 Figure 4 utilized the same water chemistry and heat  
14 load conditions as in Figure 3, using hydrogen peroxide as  
15 the corrosion inhibitor.

16 The comparative results clearly indicate the improved  
17 corrosion inhibitor capability of the peroxide based  
18 treatment.

19 Peroxycarboxylic Acid Test

20 Peroxycarboxylic acids are formed from acids selected  
21 from the group consisting of formic acid, acetic acid,  
22 citric acid, oxalic acid, gluconic acid, glucoheptonic  
23 acid, succinic acid, acrylic acid, polyacrylic acid,  
24 maleic acid, polymaleic acid, polyepoxysuccinic acid,  
25 ethylene-diamine-tetraacetic acid, malonic acid, adipic  
26 acid, phosphonobutanopolycarboxylic acid and mixtures  
27 thereof. As exemplified herein, peroxy citric acid is  
28 an equilibrium product of hydrogen peroxide and citric  
29 acid (a "solution" of a peroxy carboxylic acid is comprised  
30 of the peroxy carboxylic acid, hydrogen peroxide and the  
31 carboxylic acid). A solution of peroxy citric acid was  
32 prepared by combining a solution of citric acid, with 30%  
33 laboratory grade hydrogen peroxide. The ratio of the blend  
34 was 2:1 hydrogen peroxide to citric acid based on actives.

35 After flushing the system, 130ppm of the blend was

1       added to the water. The pH was measured at 6.8. After  
2       allowing the system to reach steady state, the ECN  
3       corrosion rate was monitored and recorded as illustrated  
4       in Figure 5.

5       The results illustrate that hydrogen peroxide and  
6       peroxycarboxylic acids (and/or respective constituents  
7       thereof) provide superior corrosion inhibition compared to  
8       the long established industry standard chromate based  
9       treatment technology.

10      Cleaning Test

11      To achieve a skin temperature of 144°F, the CHx  
12     required  $65.6412 \text{ BTU/hr.ft}^2 \times 10^3$ . This was recorded as the  
13     baseline heat transfer under steady state conditions. The  
14     CHx was then exposed to a corrosive electrolyte under  
15     stagnant conditions for several days.

16      When the circulation pump was activated, red water  
17     was observed leaving the CHx. After allowing the system to  
18     reach steady state under heat transfer, the rate of heat  
19     transfer required to achieve a skin temperature of 144°F  
20     was monitored and recorded as  $52.8664 \text{ BTU/hr.ft}^2 \times 10^3$ .

21      The lower heat transfer value indicates a 19.46%  
22     reduction in heat transfer efficiency due to the presence  
23     of corrosion byproducts (ferric oxide).

24      The electrolyte was initially treated with 1000ppm of  
25     a peroxy citric acid solution made from a 2:1 actives  
26     weight ratio of hydrogen peroxide and citric acid. Figure  
27     6 illustrates the heat transfer increased (data point 4)  
28     while ECN (Figure 7) showed a corresponding rise in  
29     corrosion rate. ECN corrosion rates then dramatically drop  
30     (data point 5), followed by the onset of a passive-steady  
31     state condition (data points 8-13).

32      By data point 12 (Fig. 6), heat transfer recovered  
33     22% of the lost heat transfer resulting from the removal  
34     of much of the insulating ferric oxide.

1       Data point 13 shows the affects of adding 1000ppm of  
2       HCl (based on active(s)). Heat transfer is completely  
3       restored while maintaining unprecedented control of ECN  
4       corrosion rate and Activity Factor (Figure 8). The  
5       "Activity Factor" (AF) is calculated using the equation:

6                    $AF = \sigma_i / i_{rms}$

7       where  $\sigma_i$  is the standard deviation of the electrochemical  
8       current noise data, and  $i_{rms}$  is the root mean square of  
9       the electrochemical current noise. The AF detects changes  
10      in current and highlights the deviation from the steady  
11      state condition.

12      Test results clearly illustrate the cleaning and  
13      corrosion inhibition capabilities of peroxydicarboxylic acid  
14      solutions. Even in the presence of high chlorides and low  
15      pH (~4.0), pitting corrosion was averted, and corrosion  
16      rates were controlled while regaining 100% efficiency.

17      This technology can also be utilized in conjunction  
18      with other corrosion inhibitors to improve their  
19      performance. Examples of such other corrosion inhibitors  
20      include but are not limited to orthophosphates,  
21      polyphosphates, phosphonates, zinc and azoles. It is  
22      further understood that the instant treatment technology  
23      could, and in many cases would be utilized with other  
24      water treatments such as deposit control agents, corrosion  
25      inhibitors and microbiological control agents.

26      It is to be understood that while a certain form of  
27      the invention is illustrated, it is not to be limited to  
28      the specific form or arrangement of parts herein described  
29      and shown. It will be apparent to those skilled in the  
30      art that various changes may be made without departing  
31      from the scope of the invention and the invention is not  
32      to be considered limited to what is shown and described in  
33      the specification and drawings.

1

2 CLAIMS

3

4 What is claimed is:

5

6       Claim 1. A method for inhibition of corrosion of a  
7 metal which experiences active-passive transition in  
8 contact with an electrolyte comprising:9       incorporating one or more hydrogen peroxide donors  
10 with said electrolyte at a concentration effective to  
11 inhibit corrosion.

12

13       Claim 2. The method in accordance with claim 1  
14 wherein said hydrogen peroxide donors are selected from  
15 the group consisting of hydrogen peroxide, sodium  
16 peroxide, potassium peroxide, calcium dioxide, sodium  
17 percarbonate, potassium percarbonate, sodium perborate,  
18 potassium perborate or mixtures thereof.

19

20       Claim 3. The method in accordance with claim 1  
21 wherein said metal is selected from the group consisting  
22 of steel(s), aluminum, titanium or mixtures thereof.

23

24       Claim 4. A method for inhibition of corrosion of a  
25 metal which experiences active-passive transition in  
26 contact with an electrolyte comprising:27       incorporating one or more peroxycarboxylic acid or  
28 constituents thereof with said electrolyte at a  
29 concentration effective to inhibit corrosion.

1       Claim 5. The method in accordance with claim 4  
2       wherein said metal is selected from the group consisting  
3       of steel(s), aluminum, titanium or mixtures thereof.

4

5       Claim 6. The method in accordance with claim 4  
6       wherein said peroxy carboxylic acids are formed from acids  
7       selected from the group consisting of formic acid, acetic  
8       acid, citric acid, oxalic acid, gluconic acid,  
9       glucoheptonic acid, succinic acid, acrylic acid,  
10       polyacrylic acid, maleic acid, polymaleic acid,  
11       polyepoxysuccinic acid, ethylene-diamine-tetraacetic acid,  
12       malonic acid, adipic acid, phosphonobutanepolycarboxylic  
13       acid and mixtures thereof.

14

15       Claim 7. A method of inhibition of corrosion during  
16       removal of deposits from a metal which experiences active-  
17       passive transition while in contact with an electrolyte  
18       comprising:

19       incorporating one or more peroxy carboxylic acids or  
20       their constituents with said electrolyte at a  
21       concentration effective to inhibit corrosion.

22

23       Claim 8. The method in accordance with claim 7  
24       wherein said metal is selected from the group consisting  
25       of steel(s), aluminum, titanium or mixtures thereof.

26

27       Claim 9. The method in accordance with claim 7  
28       wherein

1 said peroxy carboxylic acids are formed from acids selected  
2 from the group consisting of formic acid, acetic acid,  
3 citric acid, oxalic acid, gluconic acid, glucoheptonic  
4 acid, succinic acid, acrylic acid, polyacrylic acid,  
5 maleic acid, polymaleic acid, polyepoxysuccinic acid,  
6 ethylene-diamine-tetraacetic acid, malonic acid, adipic  
7 acid, phosphonobutanepolycarboxylic acid and mixtures  
8 thereof.